CLAIMS

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method of forming/defining and solving a model of the power network to effect control of voltages and power flows in a power system, comprising the steps of:

obtaining on-line/simulated data of open/close status of switches and circuit breakers in the power network, and reading data of operating limits of the network components including PV-node, a generator-node where Real-Power-P and Voltage-Magnitude-V are given/assigned/specified/set, generators maximum and minimum reactive power generation capability limits and transformers tap position limits,

obtaining on-line readings of given/assigned/specified/set real and reactive power at PQ-nodes, the load-nodes where Real-Power-P and Reactive-Power-Q are given/assigned/specified/set, real power and voltage magnitude at PV-nodes, voltage magnitude and angle at the reference/slack node, and transformer turns ratios, which are the controlled variables/parameters,

initiating loadflow calculation with initial approximate/guess solution of the same voltage magnitude and angle as those of the slack/reference node for all the other nodes referred to as the slack-start,

performing load-flow computation to calculate complex voltages or its real and imaginary components or voltage magnitude corrections and voltage angle corrections at the power network nodes providing for the calculation of power flowing through different network components, and reactive power generation and transformer tap-position indications,

decomposing a network for performing load-flow calculation in parallel by a method referred to as Suresh's diakoptics that involves determining a sub-network for each node involving directly connected nodes referred to as level-1 nodes and their directly connected nodes referred to as level-2 nodes and so on, and the level of outward connectivity for local solution of a sub-network around a given node is determined experimentally,

initializing, at the beginning of each new iteration, a vector of dimension equal to the number of nodes in a network with each element value zero, solving all sub-networks in parallel using available solution estimate at the start of the iteration, adding newly calculated solution estimates for a node resulting from different sub-networks, say 'q' number of sub-networks, in which the node is contained, in a corresponding vector element that gets initialized zero at the beginning of each new iteration, counting the number of additions and calculating new solution estimate or corrections to the available solution estimate by taking the average or root mean square value using any relevant relations in the following depending on the loadflow calculation method used, and storing it as initial available estimate for the next iteration,

$$\mathbf{V}_{\mathbf{p}}^{(r+1)} = (\mathbf{V}_{\mathbf{p1}}^{(r+1)} + \mathbf{V}_{\mathbf{p2}}^{(r+1)} + \mathbf{V}_{\mathbf{p3}}^{(r+1)} + \ldots + \mathbf{V}_{\mathbf{pq}}^{(r+1)})/q \qquad (51)$$

$$e_p^{(r+1)} = (e_{p1}^{(r+1)} + e_{p2}^{(r+1)} + e_{p3}^{(r+1)} + \ldots + e_{pq}^{(r+1)})/q \qquad (52)$$

$$f_p^{(r+1)} = (f_{p1}^{(r+1)} + f_{p2}^{(r+1)} + f_{p3}^{(r+1)} + \ldots + f_{pq}^{(r+1)})/q \qquad (53)$$

$$\Delta\theta_p^{(r+1)} = (\Delta\theta_{p1}^{(r+1)} + \Delta\theta_{p2}^{(r+1)} + \Delta\theta_{p3}^{(r+1)} + \ldots + \Delta\theta_{pq}^{(r+1)})/q \qquad (54)$$

$$\Delta V_p^{(r+1)} = (\Delta V_{p1}^{(r+1)} + \Delta V_{p2}^{(r+1)} + \Delta V_{p3}^{(r+1)} + \ldots + \Delta V_{pq}^{(r+1)})/q \qquad (55)$$

relations (51) to (55), being written alternatively as relations (56) to (60) as below,

$$\mathbf{V}_{\mathbf{p}}^{(r+1)} = (\mathrm{Re}\,((\mathbf{V}_{\mathbf{p1}}^{(r+1)})^2) + \mathrm{Re}\,((\mathbf{V}_{\mathbf{p2}}^{(r+1)})^2) + \ldots + \mathrm{Re}\,((\mathbf{V}_{\mathbf{pq}}^{(r+1)})^2)/q$$

$$+ j\ (\mathrm{Im}((\mathbf{V}_{\mathbf{p1}}^{(r+1)})^2) + \mathrm{Im}((\mathbf{V}_{\mathbf{p2}}^{(r+1)})^2) + \ldots + \mathrm{Im}((\mathbf{V}_{\mathbf{pq}}^{(r+1)})^2))/q \qquad (56)$$

$$e_p^{(r+1)} = ((e_{p1}^{(r+1)})^2 + (e_{p2}^{(r+1)})^2 + \ldots + (e_{pq}^{(r+1)})^2)/q \qquad (57)$$

$$f_p^{(r+1)} = ((f_{p1}^{(r+1)})^2 + (f_{p2}^{(r+1)})^2 + \ldots + (f_{pq}^{(r+1)})^2)/q \qquad (58)$$

$$\Delta\theta_p^{(r+1)} = (\Delta\theta_{p1}^{(r+1)})^2 + (\Delta\theta_{p2}^{(r+1)})^2 + \ldots + (\Delta\theta_{pq}^{(r+1)})^2)/q \qquad (59)$$

$$\Delta V_p^{(r+1)} = (\Delta V_{p1}^{(r+1)})^2 + (\Delta V_{p2}^{(r+1)})^2 + \ldots + (\Delta V_{pq}^{(r+1)})^2)/q \qquad (60)$$

wherein, square of any positive or negative number being positive, if the original not-squared value of any number is negative, the same algebraic sign is attached after squaring that number, and if the mean of squared values turns out to be a negative number, negative sign is attached after taking the square root of the unsigned number, V_p, θ_p voltage magnitude and voltage angle at node-p, e_p and f_p are the real and imaginary parts of the complex voltage $\mathbf{V}_p$ of node-p, symbol Δ before any of defined electrical quantities defines the change in the value of electrical quantity, and superscript 'r' indicates the iteration count,

evaluating loadflow calculation for any of the over loaded power network components and for under/over voltage at any of the network nodes,

correcting one or more controlled parameters and repeating the performing loadflow calculation by decomposing, initializing, and evaluating, and correcting steps until evaluating step finds no over loaded components and no under/over voltages in the power network, and

effecting a change in the power flowing through network components and voltage magnitudes and angles at the nodes of the power network by actually implementing the finally obtained values of controlled variables/parameters after evaluating step finds a good power system or alternatively a power network without any overloaded components and under/over voltages, which finally obtained controlled variables/parameters however are stored in case of simulation for acting upon fast in case the simulated event actually occurs.

2. A loadflow calculation as defined in claim-1 is referred to as Gauss-Seidel-Patel Loadflow (GSPL) calculation method which is characterized in using self-iteration denoted by 'sr' within a network-wide/sub-network-wide global iteration depicted by 'r' in the GSPL model defined by equation (27), wherein, PSH_p and QSH_p are scheduled/specified/known/set real and reactive power, $\mathbf{V}_p$ is the complex node-p voltage, and $\mathbf{Y}_{pq}$ and $\mathbf{Y}_{pp}$ are off-diagonal and diagonal elements of the network admittance matrix,

$$(\mathbf{V}_p^{(sr+1)})^{(r+1)} = [\{(PSH_p - jQSH_p)/((\mathbf{V}_p^{*})^{sr})^{r}\} - \sum_{q=1}^{p-1} \mathbf{Y}_{pq}\mathbf{V}_q^{(r+1)} - \sum_{q=p+1}^{n} \mathbf{Y}_{pq}\mathbf{V}_q^{r}] / \mathbf{Y}_{pp} \qquad (27)$$

3. A loadflow calculation as defined in claim-1 is referred to as Decoupled Gauss-Seidel-Patel Loadflow (DGSPL) calculation method which is characterized by a loadflow model defined by following set of equations, which represents similar complex simultaneous equations appearing in other subject areas whose real and imaginary components added as in equation (32) and then decoupled for simultaneous or successive solution,

$$I_{1p}PSH_p + I_{2p}QSH_p = A_p\,(e_p^2 + f_p^2)\,) + e_p \sum_{q>p} (BB1_p - BB2_p)\,) + f_p \sum_{q>p} (BB1_p + BB2_p) \qquad (32)$$

where,

$$A_p = I_{1p}\,(G_{pp} + g_p) - I_{2p}\,(B_{pp} + b_p) \qquad (33)$$

$$BB1_p = I_{1p}\,(e_qG_{pq} - f_qB_{pq}) \qquad (34)$$

$$BB2_p = I_{2p}\,(f_qG_{pq} + e_qB_{pq}) \qquad (35)$$

Where, equation (32) is decoupled into two quadratic equations as,

$$A_{1p}e_p^2 + B_{1p}e_p + C_{1p} = 0 \qquad (36)$$

$$A_{2p}f_p^2 + B_{2p}f_p + C_{2p} = 0 \qquad (37)$$

Where,

$$A_{1p} = A_{2p} = A_p \qquad (38)$$

$$B_{1p} = \sum_{q>p} (BB1_p - BB2_p) \qquad (39)$$

$$B_{2p} = \sum_{q>p} (BB1_p + BB2_p) \qquad (40)$$

$$C_{1p} = A_{2p}f_p^2 + B_{2p}f_p - (I_{1p}PSH_p + I_{2p}QSH_p) \qquad (41)$$

$$C_{2p} = A_{1p}e_p^2 + B_{1p}e_p - (I_{1p}PSH_p + I_{2p}QSH_p) \qquad (42)$$

Where, equations (36) and (37) can be iterated incorporating self-iteration for solution as depicted by equations (43) and (44),

$$(e_p^{(sr+1)})^{(r+1)} = [\{(-C_{1p})^r / ((e_p)^{sr})^r\} - (B_{1p})^r] / A_{1p} \qquad (43)$$

$$(f_p^{(sr+1)})^{(r+1)} = [\{(-C_{2p})^r / ((f_p)^{sr})^r\} - (B_{2p})^r] / A_{2p} \qquad (44)$$

equations (36) and (37), which are quadratic in e_p and f_p, can also be iterated without incorporating self-iteration for solution as depicted in equations (45) and (46),

$$e_p^{(r+1)} = (-B_1^r + \quad (B_1^r)^2 - 4A_1C_1^r\,) / 2A_1 \tag{45}$$

$$f_p^{(r+1)} = (-B_2^r + \quad (B_2^r)^2 - 4A_2C_2^r\,) / 2A_2 \tag{46}$$

wherein, equations (36), (43) or (45) and (37), (44) or (46) can be solved simultaneously or successively, and in successive mode either first (36), (43) or (45) and, then (37), (44) or (46) or first (37), (44) or (46) and, then(36), (43) or (45) are solved alternately, and wherein, e_p and f_p are real and imaginary parts of complex voltage at node-p, G_{pq}, G_{pp}, and B_{pq}, B_{pp} are off-diagonal and diagonal elements of real and imaginary parts of the complex admittance matrix of the network respectively, and g_p, b_p are real and imaginary components of network admittance shunts, β is acceleration factor, r is iteration count, and factors I_{1p} & I_{2p} can take any values from $-\infty, \ldots, -2, -1, 0, 1, 2, \ldots, \infty$.

4. A parallel load-flow calculation as defined in claim-1, Claim-2, and claim-3 is characterized in the use of the simplified parallel computer a server processor-array processors architecture, where each of the array processors communicate only with server processor and commonly shared memory locations and not among themselves.

5. A simple system for controlling generator and transformer voltages in an electrical power utility containing plurality of electromechanical rotating machines, transformers and electrical loads connected in a network, each machine having a reactive power characteristic and an excitation element which is controllable for adjusting the reactive power generated or absorbed by the machine, and some of the transformers each having a tap changing element which is controllable for adjusting turns ratio or alternatively terminal voltage of the transformer, said system comprising:

means defining and solving one of the Loadflow calculation models of the power network characterized in claim-1 and claim-2 or claim-1 and claim-3 for providing an indication of the quantity of reactive power to be supplied by each generator including the slack/reference node generator, and for providing an

indication of turns ratio of each tap-changing transformer in dependence on the set of obtained-online readings or given/specified/set controlled network variables/parameters, and physical limits of operation of the network components,

machine control means connected to the said means defining and solving one of the parallel loadflow calculation models of the power network and to the excitation elements of the rotating machines for controlling the operation of the excitation elements of machines to produce or absorb the amount of reactive power indicated by said means defining and solving one of the Parallel Loadflow calculation models of the power network in dependence on the set of obtained-online readings or given/specified/set controlled network variables/parameters, and physical limits of excitation elements,

transformer tap position control means connected to the said means defining and solving one of the Parallel Loadflow calculation models of the power network and to the tap changing elements of the controllable transformers for controlling the operation of the tap changing elements to adjust the turns ratios of transformers indicated by the said means defining and solving Parallel Loadflow calculation model of the power network in dependence on the set of obtained-online readings or given/specified/set controlled network variables/parameters, and operating limits of the tap-changing elements.

6. A system as defined in claim-5 wherein the power network includes a plurality of nodes each connected to at least one of: a slack/reference generator; a rotating machine; and an electrical load, and the said means defining and solving one of the Parallel Loadflow calculation models of the power network receives representations of selected values of the real and reactive power flow from each machine and to each load, and the model is operative for producing calculated values for the reactive power quantity to be produced or absorbed by each machine.

7. A system as defined in claim-6 wherein the power network further has at least one transformer having an adjustable transformer turns ratio, and the said means defining and solving one of the Parallel Loadflow calculation models of the

power network is further operative for producing a calculated value of the transformer transformation/turns ratio.

8. A system as defined in claim-5 wherein said machine control means are connected to said excitation element of each machine for controlling the operation of the excitation element of each machine, and wherein said transformer turns ratio control means are connected to said transformer tap changing element of each transformer for controlling the operation of the tap changing element of each transformer.

9. A method for controlling generator and transformer voltages in an electrical power utility containing plurality of electromechanical rotating machines, transformers and electrical loads connected in a network, each machine having a reactive power characteristic and excitation element which is controllable for adjusting the reactive power generated or absorbed by the machine, and some of the transformers each having tap changing element which is controllable for adjusting turns ratio or alternatively terminal voltage of the transformer, said method comprising:

creating and solving any of the said Parallel Loadflow calculation models of the power network as characterized in claim-1 and claim-2 or claim-1 and claim-3 for providing an indication of turns ratio of each of the tap-changing transformers and the quantity of reactive power to be supplied by each generator in dependence on the set of obtained-online readings or given/specified/set controlled network variables/parameters, and physical limits of operation of the network components,

controlling the operation of the excitation elements of machines to produce or absorb the amount of reactive power, and controlling tap changing elements of transformers to adjust transformer turns ratio indicated by means creating/forming/defining and solving any of the said Parallel Loadflow calculation models as characterized in claim-1 and claim-2 or claim-1 and claim-3 in dependence on the set of obtained-online readings or given/specified/set controlled network variables/parameters, and physical limits of operation of the network components.

10. A method as defined in claim-9 wherein said step of controlling is carried out to control the excitation element of each machine and a said step of controlling is carried out to control the tap-changing element of each controllable transformer.